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The Role Of Teeth In Mammal History

Lílian Paglarelli Bergqvist

*Federal University of Rio de Janeiro -
Rio de Janeiro, Brazil*

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Abstract

Teeth are more than hard structures for cutting, grinding and/or crushing food. Teeth, living or dead, have much to contribute to the study of ecology, paleontology, functional morphology and systematic. They are the most common mammal body part recovered in paleontological and archaeological assemblages, and one of the easiest tools for assessing mammal evolution.

The present day human teeth morphology is a result of mammal evolution, started about 225 millions of years ago. From a simple cone to a complex and diverse pattern of cones and ridges, tooth evolved (in part) as a response to the changes in Earth environment.

This paper looks for presenting an overview, of the history of mammal teeth, since its origin to the present day diversity, as long as the importance of teeth for mammals, emphasizing the contribution of paleontology to recent human tooth design, function and nomenclature

Key Words:

Teeth, evolution, mammal, diet

Correspondence to:

Lílian Paglarelli Bergqvist
Universidade Federal do Rio de Janeiro
Departamento de Geologia/IGEO/CCMN, Bl. G
Ilha do Fundão, Rio de Janeiro/RJ
20940-000
e-mail: bergqvist@ufrj.br

Introduction

Although mammalian teeth are similar in basic components, they exhibit great diversity in number, size and shape. If the fossil species are considered, this diversity is even greater. Some mammals, such as the anteater, are completely edentulous. Others, like the sperm whale, bear teeth only in the lower jaw. Some lack the mesial teeth, as the sloths. In the platypus, the dentition is represented only by some of the deciduous premolars, which are shed without replacement well before adulthood; in other mammals, teeth are present only in embryonic stages and their germs are reabsorbed before birth. This diversity of the mammalian dentition, however, was not achieved at once. Since the first known mammals (Late Triassic, H" 225 millions years [m.y.] ago), the mammalian dentition has been evolving and becoming adapted to the broad array of diets and environments that have characterized the earth during the past 225 m.y. of Earth history.

Mammalian teeth, fossil or recent, have much to contribute to the study of ecology, paleontology, functional morphology and systematics. Tooth characters have a role in phylogenetic reconstructions of primates in general and hominid interrelations in particular[1]. Different aspects of teeth can also be associated with diet, allowing the estimation of dietary specialization in extinct species. The utility of teeth in assessing diet and relationships was aptly summed up by the father of comparative anatomy, Georges Cuvier (1769-1832): "montrez-moi votre dents et je vous direz ce-que vous être."

Teeth form a prominent part of the mammal remains of paleontological and archaeological sites, as they are constructed of remarkably tough materials, and hence are the most resistant parts of the body to destruction. Sometimes, they are the only part of an animal body upon which a paleontologist or archaeologist can depend to identify extinct species. The large degree of variation in the shape and form of mammalian teeth (particularly molars) makes them readily identifiable. Thus, teeth and jaws play a major role in the identification of paleontological and archaeological material (Figure 1). While bones or bone fragments may yield little precise information, premolars and molars, mainly due to their great structural diversity related to the diverse dietary habits and genealogical backgrounds presented by various mammalian groups are of capital importance to systematic studies of mammals, both living and extinct the zoological and paleontological systematic. Even a little structural modification can be of great importance in clearing taxonomic doubts, often making it possible for a single tooth be assigned to a mammal species, and also providing information of the age, diet and behavior of the animal, and its environment. This makes comparative dental anatomy an important subject for paleontologists and archaeologists[2].

This paper seeks to present an overview of the history, importance and use of mammalian teeth, from their origin to the present diversity and, moreover, to show up the outstanding contribution that paleontology can bring to the recent human tooth design, function and nomenclature.

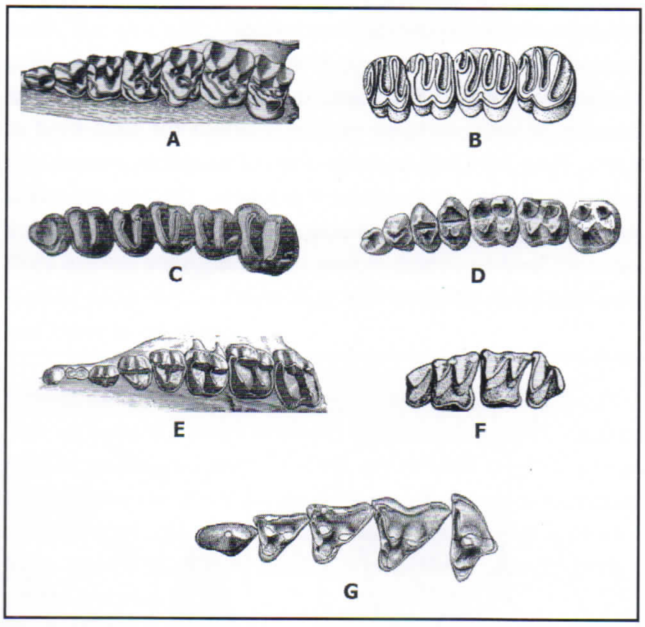

Fig. 1- *Different crown morphologies in mammalian dentition based on left upper teeth of fossil species. The possible diet is indicated in parenthesis.* ***A****, Litoptern [extinct]* Diadiaphorus *(herbivorous);* ***B****, Rodent [mices]* Theridomys *(herbivorous);* ***C****, Uintatheriomorpha [extinct]* Uintatherium *(herbivorous);* ***D****, Primate [monkeys]* Oreopithecus *(omnivorous);* ***E****, Perissodactyla [tapirs, horses]* Homogalax *(omnivorous);* ***F****, Chiroptera [bats]* Mormopterus *(insectivour);* ***G****, Marsupial [kangaroos, opossums] (carnivorous). From*[11, 35-37].

Mammal Tooth Features

Anatomical structure

Teeth are white and hard structures composed mainly of calcium phosphate in the form of crystalline hydroxyapatite and collagen fiber in different percentages. A tooth consists of two main anatomical elements, a crown and a root (or roots), joined by a cervical region, or "neck". The crown is coated by a layer of *enamel*, a hard crystalline tissue, while a bone-like material called *cement* coats the root (Figure 2). Underlying these surface layers, and forming the main structure of the tooth, there is a very tough and resilient tissue, the *dentine*. Inside the tooth there is a *pulp chamber*. The dividing line between the different parts of the teeth can be called enamel/dentine junction (EDJ), cement/dentine junction (CDJ) and cement/enamel junction (CEJ). Mammalian tooth enamel is distinct from that of other tetrapods in having prisms, at least in incipient form, wherein flat, open prism sheaths and planar prism seams are present[3].

All of these elements are present in even the most complex tooth. The crown may be wider, taller or flatter; it may include extra mounds, known as cusps, or folds in the enamel layer; cement may cover the crown as well as the root[2]. The form and pattern of the crowns and roots vary depending on the kind of teeth and animal species. Carnivorous mammals bear narrower crowns with sharp and high cusps, while in omnivores the crown is wider and the cusps are numerous and blunt. In herbivores, in the place of tubercles, there are irregular crests delimiting depressions.

A tooth may possess one or more roots that vary according to the main group function, location and specialty. The number of roots is more or less constant for each kind of tooth. They are fixed in the sockets of mandible, pre-maxilla and maxilla by periodontal ligaments. Stretch receptors associated with these ligaments provide sensory feedback on tooth loading, which in turn is critical to the precise tooth occlusion that characterizes mammals[4].

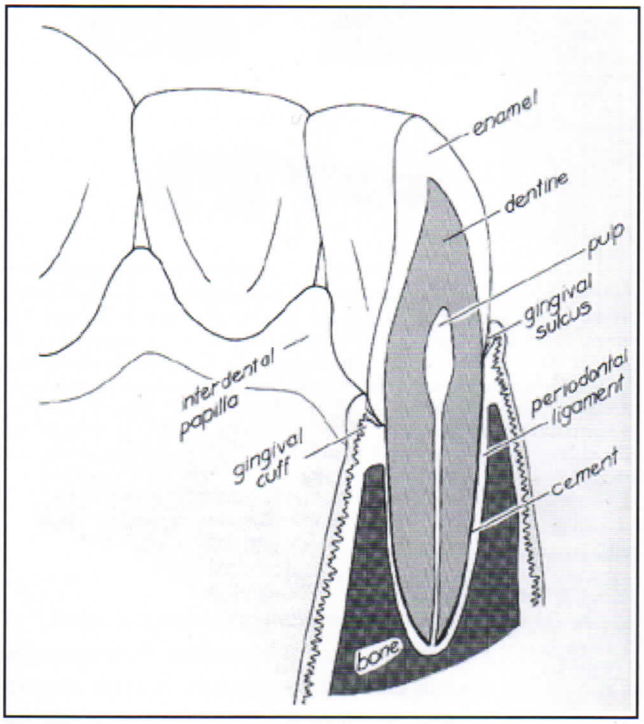

Fig. 2 - Tooth structure. From[2].

Types

The characteristic heterodont dentition of mammals was already established by the Late Triassic-Early Jurassic (about 220 m.y.), as exemplified by the well-known *Morganucodon*[56]. Differentiation of the dentition reflects a regional distribution of function: the anterior teeth, being farther from the articulation of the jaw, have a great range and speed of movement, whereas the cheek teeth (premolars and molars), situated nearer to the muscles, exert great occlusal pressure[7]. The most distinctive features of mammalian heterodonty are the crowns of the cheek teeth, which are folded into diverse and complex shapes. The basic morphological entity of the crown pattern is the cusp, a conical projection from the crown. Additional features of the crown surface are ridges, crests and cingula, which are ridges passing around the base of the crown[8].

The same four groups of human teeth - incisors (I), canines (C), premolars (P) and molars (M) - are present in all mammals (except where lost), although the number of each varies from one species to the next and some may be lacking. The primitive dental formula (including one side only) of placental mammals (a high taxonomic level that groups all recent mammals but marsupials and monotremes) is I 5/4, C 1/1, P 4or5/4or5, 3/3 M teeth[9]. The dental formula of primitive mammals (non-placental) is larger, sometimes reaching 32 teeth only in the mandible. Uncertainty in the premolar count stems from varying interpretations of premolar homologies in Cretaceous eutherians. During the course of mammalian evolution, tooth reduction occurred in many different lineages. From this it might be speculated that the primitive placental formula was composed of 48 teeth, which accords with the hypothesis that a count of four molars is primitive for the common ancestor of marsupials and placentals[10]. Paula-Couto[11] considered it a possible hypothesis, once marsupial mammals, which have derived from the same ancestral stock as placentals, bear 4/4 molars.

Long or short interruptions of the tooth series, known as diastemata, can be present between incisors, or between the last incisor and canine, or between this and the first premolar. The human dentition has no diastemata and constitutes a continuous or closed series. This is one of the features that differentiate members of Hominidae from other primate families[11]. There is a tendency among civilized human races toward loss of the third molar, whereas in some Australians and Africans an upper and lower fourth molar may be occasionally found.

Incisors are the teeth fixed in premaxillary bone and mesial part of the dentary. They are generally chisel-shaped, and have the function of grasping and cutting, but can assume other roles, such as defense (as in elephants) or grooming (Felidae, Cynocephalidae). Incisors are lacking in edentates (armadillos and sloths); in ruminants, they are present only in the lower jaw, whereas in elephants they are present only in the upper. They are frequently brachiodonts, but in some species (e.g., Lagomorpha, Rodentia) they are ever-growing, or hypselodonts. Incisors are typically bucolingually compressed, single-cusped and uniradiculated; sometimes they are caniniform. In elephants, the incisors enamel is present in helicoidal bands, and in rodents solely in the buccal face. No true primate (including human) has a third incisor.

Canines, like incisors, have a simple crown; modern species have a single-rooted canine, but two are often present in early mammals (e.g.[12]). In general they are they are the tallest teeth in the mouth and are strongly curved, but in horses and deers they are incisoform. In herbivorous species the canine is frequently reduced or absent (e.g. rodents, edentates, and rabbits), or its presence can be sexually dimorphic (canines are present only in male horses).

Premolars and molars (cheek teeth) have the most complex crowns and generally have two or more roots. Premolars are usually smaller than molars, and have fewer cusps. They are variable in number. In extant marsupials the number of molars (4) is larger than premolars (3). The teeth that are lost in evolution tend to be those at the margins of tooth classes[5]. In humans, the two premolars present correspond to the third and fourth premolars of non-human mammals.

Differentiating teeth are characterized as deciduous (= primary, milk) or successional (= permanent, secondary), on the basis of their relationship with dental lamina[13]. The primary dentition differentiates from buds that develop at the free end of the primary dental lamina. The deciduous tooth become secondarily displaced bucally during the middle-late bell stage, concomitant with differentiation of its successional lamina[13], that will for the permanent teeth.

The prefix d (or D) indicates deciduous teeth (e.g. di^2 or dI^2 = deciduous second upper incisor; dP$_3$ or dp$_3$ = deciduous third lower premolar). Deciduous premolars are also known as deciduous molars, as their shape (number of cusps and roots) are closer to molars and they have the same molar function in milk dentition. For this reason they are often represented as dM. However, their designation as deciduous molars is confusing, as molars are, by definition, never replaced.

As in humans, deciduous premolars are structurally closer to molars of "permanent" dentition than to the successional premolars. They form, with molars, a continuous morphological series originated from the primary dental lamina[13]. The sequence of development of tooth germ is variable within mammals, but usually dC is one of the earliest germs to differentiate in eutherians, while dP1, when present, is always the last deciduous tooth to differentiate, probably because a successor for dP1 is normally absent[13], hence, it is a retained deciduous premolar. So, molars and P1, based on their ontogenetic origin, are "permanent" deciduous teeth with no successional teeth rather than being permanent teeth without deciduous. However, the enamel hardness and thickness difference between deciduous premolars and molars is expected once they are differently adapted for different needs, and mineral-building resources might be in short supply in younger individuals. There may be also some morphogenetic development within the lamina itself that causes the products (teeth) to vary according to when they are formed (Cifelli, per. com.).

Since they do the major job of masticating food, molars (and premolars, in advanced taxa in which they are molariform) are the teeth that exhibit the greatest diet-related diversity[14]. The structure of the cheek teeth is also one of the most important criteria in mammalian classification.

Size and growth

The size and growth of a mammal tooth is diet dependent. Human teeth, like those of any other omnivorous mammal, are low crowned (brachyodont), with long, closed roots. A similar pattern is found among carnivores. Grass is very abrasive and brachyodont teeth would be rapidly worn away in a grazing animal[15]. As a result, a higher crowned cheek-teeth has evolved among mammals depending on grasses for a substantial part of their diet. Molar of most herbivorous are relatively high crowned (mesodont), with roots closed. In horses, the teeth grow for a long time in relation to animal's life, bearing a higher crown. When they stop growing, the roots close. This kind of teeth is called hypsodont (or euhypsodont). In other animals (e.g. sloths), the teeth are ever-growing (hypselodont or protohyposodont). In this type of teeth the crown is high, the roots are short and open and there is no neck.

Crown morphology

The structures on the occlusal surface of a tooth receive special names and most of them are present in all mammal teeth. However, each mammal species presents a particular shape of each accident or lack some of them. So, each species has a particular pattern, making it possible to identify even a single isolated tooth.

Most of the dental accidents, with the terminology used in nonhuman mammals, are illustrated in the Figure 3.

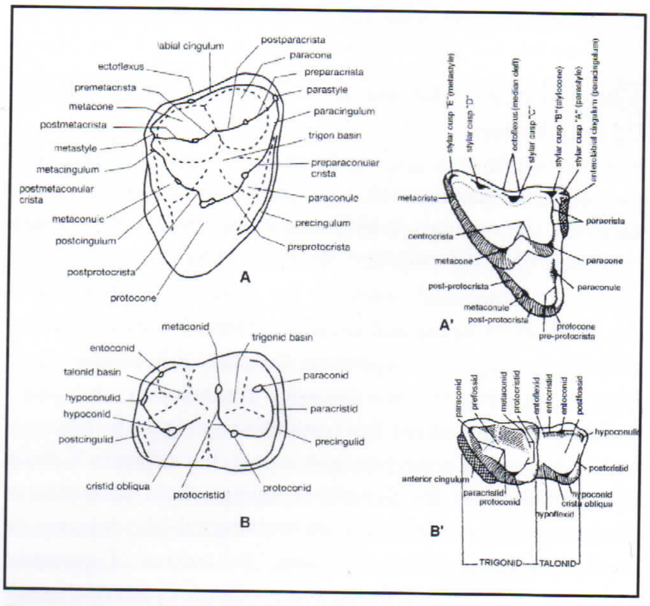

Fig. 3 - Terminology used for molar morphology in placental (A, B) and marsupial (A', B') mammals. ***A** and **A'** right upper molar; **B** and **B'** right lower molar. All in occlusal view. From*[38-39].

Dental nomenclature is based on superficial features, and in this regard differs substantially from the terminology employed for non-human mammals. Table 1 presents a correlation of cusp terminology between the two systems (human terminology was based in[16]).

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Correspondence between human and non-human dental terminology.

Teeth	Upper		LOWER	
	Human	Non-human	Human	Non-human
Premolars	Buccal	Paracone	Buccal	Protoconid
	Lingual	Protocone	Mesiolingual	Metaconid?
	xxxxxxx	xxxxxxx	Distolingual	Hipoconid?
First(1) and Third Molars	Mesiobuccal	Paracone	Mesiobuccal	Protoconid
	Distobuccal	Metacone	Distobuccal	Hipoconid
	Mesiolingual	Protocone	Mesiolingual	Metaconid
	Distolingual	Hypocone	Distolingual	Entoconid
	xxxxxxx	xxxxxxx	Distal	Hipoconulid
Second Molar	Mesiobuccal	Paracone	Mesiobuccal	Protoconid
	Distobuccal	Metacone	Distobuccal	Hipoconid
	Mesiolingual	Protocone	Mesiolingual	Metaconid
	Distolingual	Hypocone	Distolingual	Entoconid

(1) First upper molars sometimes bear a supplemental cusp, united to and somewhat lingual to the mesiolingual cusp, called cusp or tubercle of Carabelli. This morphological trait can take the form of a well-developed fifth cusp and is used to distinguish populations [16]. Non-human mammals do not have any cusp in the same place as the tubercle of Carabelli (mesiolingual to protocone). The closest feature is a style in the mesial cingulum, ahead of protocone (protostyle), but it can be present either in the first or in the second upper molar, and it is not the case in humans.

A Brief Review of Mammal Teeth Origin and Its Evolution to Primate Pattern

It is impossible to dissociate the origin of mammal teeth with the origin of mammals as a group. Mammals are advanced members of a group of amniotes named Synapsida, which separated from the "reptiles" at least 325 m.y. ago. Although the term "Synapsida" refers to the position of openings in the skull, early synapsids already presented a hypertrophied caniniform (Figure 4) separating the conical homodont teeth (single-cusped) in two groups (pre-canines and post-canines). The transition from primitive synapsid to mammal took place not in a single quantum leap but rather in a series of stages. Among the Synapsida lineage, the Cynodontia is the group that presents the most mammal-like features in teeth, skull and skeleton. During the course of synapsid evolution, the teeth became more complex, bearing small mesial and distal accessory cusps and an internal cingulum, implying in some degree of food-processing in the mouth[17]. Many mammal-like features evolved in different cynodont lineages, but the arbitrary boundary between mammals and non-mammalian synapsids is generally defined by the presence (in mammals) of a functional, condylar temporomandibular joint between the dentary and the squamosal[18]. Additional features shared by these early mammals are: divided postcanine roots and four rather than three lower incisors[17].

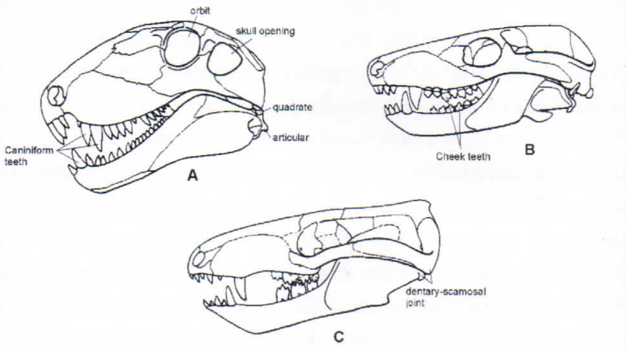

***Fig. 4 - A**, Early Synapsida skull (*Dimetrodon*) showing the opening and the developed caniniform teeth e postcaniniform teeth unicuspidated; **B**, Cinodont skul (*Thrinaxodon*) showing the multicuspidate cheek teeth; **C**, A primitive mammal (*Sinoconodon*) showing the typical mammalian jaw-joint. Modified from[2,21].*

Mammal-like reptiles and some primitive mammals were polyphiodont (many tooth generations). However, the ability of regulating internal temperature (endothermy) evolved in mammal linage, requiring more food-processing to produce calories to keep the body warm and permit sustained levels of high activity. A diphyodont pattern, with one generation of milk teeth followed by a second generation of permanent teeth, would fulfill a better performance in food-processing, as teeth classes could work more properly. Most mammals are diphyodont, but in some cases (marsupials), only the third premolar (P3) is replaced, while in others (rodents) there is only one dentition. This last evolutionary trend results ultimately in a more evolved condition (monophyodonty).

Cope[19] and Osborn[20] first developed the theory of mammalian molar evolution that is generally accepted today. Osborn[20] also proposed a nomenclature for the various tooth cusps and elements. The Osbornian terminology was based on a system of prefixes and suffixes, which signify type, position, relationships of dental elements, and also intended to imply evolutionary process and tendencies. Differently, in dentistry, purely location terms for cusps are generally used. The suffix "id" is used to designate the lower tooth elements. The suffix *cone/conid* is employed for the main cusps of trigon (id) and talon (id). Trigon is the name of the triangular arrangement of the three main cusps of upper and lower cheekteeth, while the low crushing region of a cheektooth, at its distal end is called talon. It is more developed in lower teeth. *Conule* is used for diminutive cusps or cuspules rising from cristae (ids); *styles* (id) identify tubercles or "pillars" rising from the cingula or cingulids and *loph* (id) refers to any ridge or crest. The prefixes *proto*, *para*, *meta*, *meso*, *hypo*, *ecto* and *ento* refer to the supposed primitive order of development of dental elements[22].

According to the Cope-Osborn theory, the primitive form of the tooth in upper and lower jaws was a perfectly simple cone (as in many reptiles, like crocodiles). Aligned with this were added small mesial and distal cusps (*cusp-in-line pattern*). The next step consisted in shifting of the relative position of these three cusps to form triangular cusp arrangements that are reversed, upper to lower (*tritubercular pattern*) (with the reptilian cone [protocone] lingual in the upper jaw and [protoconid] buccal in the lower jaw).

Paleontological evidence and studies on tooth ontogeny brought to life some inconsistencies of the Cope-Osborn theory. A study of the sequence of cusp development and calcification of man, monkey, opossum and of some insectivores, carnivorous, ungulates and rodents (see[22]) have shown that the paracone in the upper and the protoconid in the lower are invariably the first cusp to develop and calcify (the reptilian cone). The second cone to develop in the upper teeth is the protocone, then the metacone, hypocone and hypoconule. Lower cones usually develop in the same sequence and in the same position as the upper relative to each other. Thus, the protoconid is followed by the metaconid, or the paraconid, if present; the entoconid is followed, sometimes preceded by the hypoconid. The hypocone and hypoconulid are last to develop in the more highly complex upper and lower molars, respectively.

Several fossil studies, most notably that of[23], corroborated the above-mentioned ontogenetic studies, and showed the sequence of events of the evolution from the tritubecular pattern (protocone(id), paracone(id) and metacone(id) arranged in triangle – the trigon(id)) to the tribosphenic molar pattern (Figure 5), in which a talon/talonid, formed by hypocone/hypoconid, hypoconulid and entoconid, is added to the tooth. Tribosphenic molars are capable of both shearing (*sphen*) and grindind (*tribein*), providing more versatile occlusal functions than the primitive teeth that have simple, wedge-like trigonids limited to shearing, which are the most important dental features of marsupials and placentals. The increase versatility of this functional complex is considered to be the precursor condition to many mammalian dental specializations that correlated with the adaptive radiations of marsupials and placentals[24].

Seeking for a terminology that truly illustrates the dental elements ontogenetic sequence and homologies, Herskovitz[22] proposed a new dental terminology. Although the equivocal homologies implicit in the Osbornian terminology were early recognized, the terms have become established and students of dental morphology and evolution continued to use them in spite of Hershkovitz terminology. The most useful summary of the evolution of the mammalian molar pattern is that of[25].

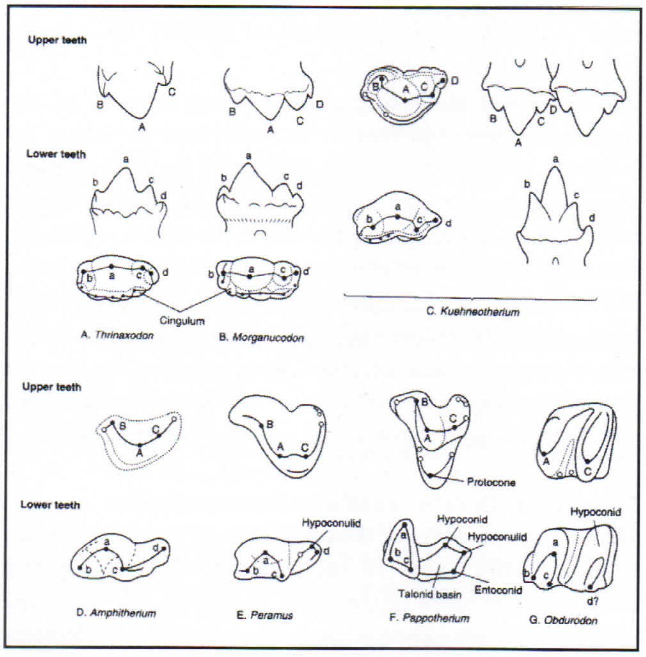

Fig. 5 - *Cheek teeth of an advanced cynodont synapsid (A), a mammaliaform synapsid (B), and mammals (C-G), showing important stages in the evolution of tribosphenic molars. In each set of drawings the upper images represents right upper (maxillary) teeth; shown immediately below the upper teeth are the left lower (dentary) teeth. Cusps of lower teeth are drawn directly bellow the position in which they occlude with the upper teeth. Presumed homologous cusps are indicated by capital letters in upper teeth and lowercase letters in lower teeth:* A=*paracone;* B=*stylocone;* C=*metacone;* D=*metastyle?;* a=*protoconid;* b=*paraconid;* c=*metaconid;* d=*hypoconulid. Lateral views of the teeth are given in (A), (B) and (C) to show the positions of these teeth as they would be just before they occlude and shear past one another. In addition, occlusal views are shown in all cases, and in (C) through (G) the uppers are shown slightly staggered relative to the lowers, as they would be in their natural positions. In* Amphitherium *the upper teeth are unknown; this reconstruction is hypothetical. (After[40]).*

Most non-human primates have dentition similar to that of humans, and the early evolutionary of primate teeth provides essential background for interpreting the human dentition. Butler[7] offers a good summary of primate tooth evolution, which is briefly cited here. Primates presumably derived from a Cretaceous (H” 70 M.y.) insectivorous ancestor with tribosphenic molars. In these teeth, the upper molar was triangular, with an elevated paracone and metacone and a lingual protocone. The mesial and distal margins of the trigon basin were formed by preprotocrista and postprotocrista crests, and minor cusps, paraconule and metaconule, developed on these. A narrow stylar shelf, which disappeared in most eutherians, occupied the buccal border of the tooth. The lower molar consisted of a mesial wedge-like trigonid and a distal basin-like heel (talonid). The trigonid was formed by protoconid buccally, and paraconid and metaconid lingually. The talonid, much lower than trigonid, had three cusps surrounding a basin: hypoconid buccally, hypoconulid distally and entoconids lingually.

The spread of flowering plants during the end of the Cretaceous period provided vast new food resources for mammals, primarily (at first) in the form of reproductive parts. Change in the physical nature of the food led to adaptive modifications of the molars, including a reduction of piercing and cutting in favor of crushing and grinding. The paracone and metacone on the upper molar and the trigonid of the lower molar were reduced in height and became more inflated. The trigon basin was enlarged by broadening the lingual part of the tooth, and the talonid basin was widened. Other modifications are related to the occlusion pattern (see[7]).

Mammal Tooth Pattern and Its Adaptation to Diet

Much of the diversity of dentition patterns among mammals involves differences in the number, size, shape and arrangement of cusps of the cheek teeth. The size and shape of teeth have long been recognized as important indicators of diet and dental function[26]. The variety of dental features allows the distinction of different types of crown morphology (Figure 6), and each type presents a functional adaptation related to the kind of food processing. The main types are: bunodont, lophodont, "lambdadont" and secodont.

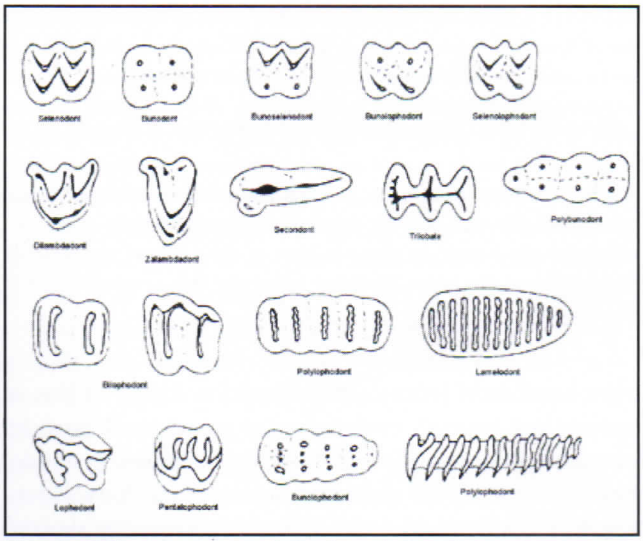

Fig. 6: Different patterns of cheek tooth morphology in mammals, seen in occlusal view.

The cheek tooth morphology possessed by omnivorous, frugivorous or generalist carnivorous mammals is termed *bunodont*. Bunodont cheek teeth are low-crowned and rounded-cusped, and typical of pigs, bears and humans. More folivorous mammals, such as horses, rhinos and deers, for instance, have lophed teeth. In these cheek teeth, the low, isolated cusps of the bunodont form of tooth have been run together to form high, cutting ridges, or lophs, that act to shear and shred food as leaves[27]. When the lophs are crescentic and longitudinally oriented, the tooth is called *selenodont*, whereas when they are transversely oriented, the tooth is termed *lophodont*. *Secodont* or carnassial is a specialized type of tooth present in carnivorous mammals (mainly in Felidae), in which the cusps are mesiodistally elongated and straight. The upper and lower carnassials work together to provide a scissors action for shearing flesh. Insectivorous mammals present the "lambdadont" tooth pattern, which is characterized by one (*zalambdadont*) or two (*dilambdodont*) buccal ridges of inverted lambda (L) shape. These sharp-bladed teeth are useful in cutting and crushing the hard chitinous exoskeletons of insects[14].

The trilobate pattern of tooth is present only in primitive relatives of armadillos. In this peculiar kind of tooth there are prominent ridges of osteodentine in the middle of modified orthodentine, which is little resistant to wear[28]. These ridges are highly resistant to abrasion and very appropriated to folivorous (grazers) mammals.

Food is one of the main dimensions of an animal environment, and if we can infer an animal's food from its anatomy, then we can reconstruct diet in extinct taxa[1].

The Role of Tooth in Estimating Age and Body Size in Fossil Mammals

The age of a mammal can be estimated by the degree of tooth wear. The rate of wear depends on diet and environmental factors[29], the overall morphology of the crown (disposition, height of cusps and depth of fissures), the area of occlusal surface, thickness and microstructure of enamel and, in some cases, hypoplasia[2]. It is possible to assign absolute ages to fossil individuals by fitting comparative data on attrition rate from living population, but this procedure involves the assumption that the living animals of today are comparable in the foregoing respects to those represented by fossils[2]. Although Hutton's concept of uniformitarianism ("the present is the key to the past") is fundamental to the geological sciences, this assumption is not always warranted when it comes to determining age of fossil individuals. Hence, such determinations are more properly viewed as "suggested or approximate" ages, rather than absolute ages. Notwithstanding these difficulties, teeth often provide the only direct evidence for estimating an animal's age, and this estimation can provide key insight for understanding the possible cause of death, whether of an individual or a population.

In hominids, the approximate age of death can be determined, beside the degree of wear on teeth, by the state of dental eruption. In Lucy's mandible, for example, the third molar was erupted and just beginning to show wear, leading to the conclusion that Lucy was fully adult when she died[30].

Body size plays a major role in studies of mammalian paleoecology, and may be the most useful predictor of species' adaptation to a habitat; it also has an important role to play in studies of tempo and mode of evolution[31]. Estimates of body size based on limb measurements are more reliable than those based on dental measurements. However, because of their identifiability, preservability and frequency in a fossil assemblage, teeth will continue to play a pre-eminent role in body mass estimation[31].

The M_1 and M_2 have become widely used for prediction of body mass, as in most extant species these are the teeth with the least size variation[32]. In some groups, tooth length is a better estimator of body size than tooth width and area, which are more related to diet[33]. Some studies have shown that the length of the series P_4-M_3 presents the highest coefficient of correlation with body mass (see[34]), unfortunately, it is not a very useful variable for fossil species, as in most fossil assemblages isolated teeth are the commonest fossils (the establishment of a regression equation for prediction of body size requires a considerable number of specimens of the same tooth or series of teeth).

Final Comments

Teeth are more than hard structures for cutting, grinding and/or crushing food. They are tools of outstanding importance for understanding mammal evolution and relationships, and for estimating fossil mammals size, age of death and diet.

It is important that dentists become conscious that present day human teeth morphology, structure and physiology are a result of millions of years of evolution from a simple cone to a complex pattern of cusps and ridges, a process guided (in part) by the changes in environment through time.

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